ENGLISH

TRANSLATION OF

OF INTERNATIONAL

APPLICATION AS FILED

DESCRIPTION

RADIO RECEIVER AND RADIO TRANSMITTER

Technical Field

The present invention relates to radio receivers and radio transmitters that avoid the influence of frequency drifts in oscillation circuits that generate carriers, local oscillation signals, and the like.

Background Art

In radio communication, such as a keyless entry system that requires a short time to transmit and receive a control code having a short length, a radio transmitter transmits a radio signal on which information, such as an identification code and a control code that are allocated for each object, is superimposed, and a radio receiver receives the radio signal and demodulates the codes. Then, in accordance with the demodulated codes, a controller authenticates the object and locks/unlocks a door.

In order to realize such radio communication, the radio transmitter must include an oscillation circuit that oscillates a high-frequency signal, which functions as a carrier, and the radio receiver must include a local oscillation circuit that performs frequency conversion. In addition, the radio signal must be transmitted and received in a state in which each of the frequency of the carrier of the radio signal from the radio transmitter and the frequency of the local oscillation circuit of the radio receiver is stabilized to a predetermined value.

However, generally, a frequency drift in which an oscillation frequency varies in accordance with a temperature change, a time-lapse change in a circuit constant, and a time-lapse change in an oscillator may occur in an oscillation circuit necessary for transmission or reception of radio signals. If a carrier frequency of a radio signal

transmitted from the radio transmitter or an oscillation frequency of the local oscillation circuit of the radio receiver deviates from a predetermined value due to such a frequency drift, the frequency of an intermediate-frequency signal acquired by mixing the radio signal with the local oscillation signal in the receiver deviates from a predetermined value. Thus, there is a problem in that if the deviation of the intermediate-frequency signal increases, transmission and reception of the radio signal cannot be performed.

When a wide frequency band is used for a radio signal, the problem of a frequency deviation can be neglected even if a certain amount of frequency drift occurs. In contrast, signal noise when a radio signal is received increases in proportion as the frequency bandwidth for the radio signal increases. Thus, a problem occurs in that the reception sensitivity is reduced and communication reliability, such as a BER (Bit Error Rate), decreases. Thus, the communication reliability must be improved by using a narrow frequency band for the radio signal.

Normally, in a case where there is a need to perform transmission and reception of a radio signal under the above-described conditions that a narrow frequency band is used for the radio signal, a method in which the influence of a frequency drift is avoided without degrading the communication reliability even when the narrow frequency band is used for the radio signal by using an oscillator having a temperature compensation function, such as a TCXO, as a reference oscillation signal source is adopted. According to this method, since a frequency drift is suppressed using the oscillator having the temperature compensation function, even if the frequency bandwidth for a radio signal is narrowed, transmission and reception of the radio signal can be stably performed. However, when the oscillator having the temperature compensation function, such as a TCXO, is used, the unit cost of such an oscillator is relatively higher than a simple oscillator. Thus, there is a problem in that the high unit cost

becomes a factor of an increase in the cost of the entire radio communication system.

Thus, radio communication systems that realize communication by correcting the influence of a frequency drift without using such an oscillator having the temperature compensation function, such as a TCXO, are proposed in Patent Documents 1 and 2.

In Patent Document 1, in advance, prior to transmission of information to be communicated, a radio transmitter performs FSK modulation on a signal including a bit synchronization signal and transmits the FSK-modulated signal (a preamble method), and a radio receiver receives the signal and controls a local oscillation circuit to have a frequency at which the level of the reception signal is maximized. The radio system described in Patent Document 1 ensures establishment of communication by synchronizing, in advance, the frequency of the local oscillation circuit of the radio receiver with a frequency corresponding to a carrier frequency.

In addition, in Patent Document 2, a radio receiver sweeps an oscillation frequency of a local oscillation circuit, monitors the strength of a reception signal (RSSI: Radio Signal Strength Indicator), and stops sweeping the oscillation frequency when the strength of the reception signal reaches a high level. Accordingly, the oscillation frequency of the local oscillation circuit is adjusted. In addition, when the strength of the reception signal reaches a high level, the bandwidth of an IF signal filter is switched from a wide bandwidth to a narrow bandwidth. Accordingly, the BER is reduced, and the reception sensitivity is improved.

In the communication systems described in Patent Documents 1 and 2, even if the frequency bandwidth for a radio signal is narrowed, the influence of a frequency drift can be avoided. In contrast, however, the communication system based on the preamble method described in Patent Document 1 requires a circuit for switching between a bit

synchronization signal or the like and a radio signal. Thus, this communication system requires a complicated large circuit. In addition, the communication system described in Patent Document 2 requires an RSSI monitoring circuit, a plurality of filters, a filter switching circuit, and the like. Thus, this communication system also requires a complicated and large circuit, and has a problem of degradation of communication reliability. As described above, in the known procedures, the number of component parts increases, and the area of an IC increases. Thus, these known procedures have a new problem in that such increases become factors of an increase in the cost of the entire radio communication system.

Patent Document 1: Japanese Unexamined Patent Application Publication No. 08-139773

Patent Document 2: Japanese Unexamined Patent Application Publication No. 11-348732

Disclosure of Invention

Problems to be Solved by the Invention

As described above, in the known procedures, the influence of a frequency drift can be avoided while ensuring communication reliability by narrowing the frequency bandwidth for a radio signal. However, at the same time, a circuit is complicated, the number of component parts increases, and the area of an IC increases. Thus, the known procedures have a problem in that such increases become factors of an increase in the cost of the entire communication system.

Accordingly, an object of the present invention is to provide a radio receiver and a radio transmitter that avoid the influence of a frequency drift while ensuring communication reliability and that have a simple configuration with a low cost.

Means for Solving the Problems

(1) A radio receiver according to an aspect of the present invention includes an oscillation frequency control circuit that

repeatedly sweeps an oscillation frequency of a local oscillation circuit without stopping over a frequency bandwidth that is equal to or more than the width of a frequency drift in a carrier frequency of a radio transmitter that transmits a radio signal or over a frequency bandwidth that is equal to or more than the width of a frequency drift in the oscillation frequency of the local oscillation circuit. Sweep is not stopped at any frequency in the middle of a sweep operation.

As described above, sweeping the oscillation frequency of a local oscillation signal enables demodulation of a transmission signal superimposed on a carrier, as described below.

A superheterodyne radio receiver that mixes a radio signal with a local oscillation signal so as to be converted into an intermediate-frequency signal is first considered. For the superheterodyne radio receiver, when an oscillation frequency of the local oscillation signal is swept, the frequency of the intermediate-frequency signal is accordingly swept.

When a frequency drift occurs in a carrier from a radio transmitter, if the frequency of the local oscillation circuit of the radio receiver is swept over a frequency bandwidth that is equal to or more than the width of the frequency drift in the carrier, the frequency of the intermediate-frequency signal varies over a frequency band including a design value. Thus, in the process of the sweep operation, the intermediate-frequency signal temporarily has a frequency at which a radio signal can be received, and a transmission signal can be demodulated. Accordingly, as a result, the drift in the carrier frequency is compensated for.

In addition, in a case where a frequency drift from a proper value occurs when a signal for sweep is not applied to a local oscillation signal of the radio receiver, if the frequency of the local oscillation circuit of the radio receiver is swept over a frequency bandwidth that is equal to or more than the width of the frequency

drift in the local oscillation signal, the frequency of an intermediate-frequency signal varies over a frequency band including a design value. Thus, in the process of the sweep operation, the intermediate-frequency signal temporarily has a frequency at which a radio signal can be received, and a transmission signal can be demodulated. Accordingly, as a result, the frequency drift in the local oscillation signal is compensated for.

A direct-conversion radio receiver in which, for example, using a quadrature detector, a high-frequency signal from an antenna is directly multiplied by a local oscillation signal so as to be converted into a baseband quadrature signal and demodulation is performed is considered next. For the direct-conversion radio receiver, since a carrier frequency is selected based on the frequency of the local oscillation signal, if an oscillation frequency of the local oscillation signal is swept, a received carrier frequency is equivalently swept.

When a frequency drift occurs in a carrier from a radio transmitter, if the frequency of a local oscillation circuit of the radio receiver is swept over a frequency bandwidth that is equal to or more than the width of the frequency drift, a received carrier frequency varies over a frequency band including a design value. Thus, in the process of the sweep operation, a radio signal of a predetermined carrier frequency is temporarily received, and demodulation is performed. Accordingly, as a result, the drift in the carrier frequency is compensated for.

In addition, in a case where a frequency drift from a proper value occurs when a signal for sweep is not applied to a local oscillation signal of the radio receiver, if the frequency of the local oscillation circuit of the radio receiver is swept over a frequency bandwidth that is equal to or more than the width of the frequency drift in the local oscillation signal, a received carrier frequency

varies over a frequency band including a design value. Thus, in the process of the sweep operation, a radio signal of a predetermined carrier frequency is temporarily received, and demodulation is performed. Accordingly, as a result, the frequency drift in the local oscillation signal is compensated for.

Accordingly, unlike known technologies, a radio receiver and a radio transmitter do not need to detect respective frequency drifts, to perform feedback, and to achieve synchronization. Thus, the influence of a frequency drift can be avoided with a simple circuit configuration.

(2) A radio transmitter according to an aspect of the present invention includes an oscillation frequency control circuit that repeatedly sweeps an oscillation frequency of an oscillation circuit over a frequency bandwidth that is equal to or more than the width of a frequency drift in a local oscillation frequency of a radio receiver that receives a radio signal or over a frequency bandwidth that is equal to or more than the width of a frequency drift in the oscillation frequency of the oscillation circuit. Sweep is not stopped at any frequency in the middle of a sweep operation.

As described above, since the oscillation frequency of the oscillation circuit is swept in the radio transmitter, a radio receiver is capable of demodulating a transmission signal superimposed on a carrier, as described below.

When the oscillation frequency of the oscillation circuit is swept in the radio transmitter, the frequency of the carrier is accordingly swept.

In a case where a frequency drift from a proper value occurs when a signal for sweep is not applied to an oscillation frequency of the oscillation circuit of the radio transmitter, if the frequency of the oscillation circuit of the radio transmitter is swept over a frequency bandwidth that is equal to or more than the width of the frequency

drift, the frequency of a carrier varies over a frequency band including a design value. Thus, in the process of the sweep operation, the frequency of the carrier is temporarily a frequency at which a radio receiver is capable of performing reception, which is a design value, and a transmission signal can be demodulated. Accordingly, as a result, a drift in the carrier frequency is compensated for.

In addition, when a frequency drift occurs in a local oscillation signal of a radio receiver, if the frequency of the oscillation circuit of the radio transmitter is swept over a frequency bandwidth that is equal to or more than the width of the frequency drift in the local oscillation signal, the frequency of a carrier varies over a frequency band including the frequency drift in the local oscillation signal of the radio receiver. Thus, in the process of the sweep operation, the frequency of the carrier is temporarily a frequency at which the radio receiver is capable of receiving a radio signal, and a transmission signal can be demodulated. Accordingly, as a result, the frequency drift in the local oscillation signal is compensated for.

Accordingly, unlike known technologies, a radio transmitter and a radio receiver do not need to detect respective frequency drifts, to perform feedback, and to achieve synchronization. Thus, the influence of a frequency drift can be avoided with a simple circuit configuration.

(3) In addition, the transmission signal is a digital data signal including an error correction code.

Thus, even if all the codes of a digital data signal cannot be received and communication reliability, such as a BER, is somewhat insufficient, a code can be recovered, and predetermined control and the like can be performed.

(4) In addition, the transmission signal is a digital data signal in which codes having identical content are repeated within a repetition period in which the oscillation frequency control circuit

sweeps the oscillation frequency.

As described above, when codes that have a relatively short length and that include the same content are repeatedly transmitted, it takes a short time to perform information transmission of each of the codes. Thus, even if a period during which the radio receiver is capable of performing reception and demodulation is short, communication can be performed within the period. In addition, since codes having the same content are transmitted and received a plurality of times, the codes having the same content are transmitted and received over almost the whole frequency band in which a frequency changes due to sweep. Thus, demodulation of a transmission signal can be performed using a code with the best communication reliability, such as a BER, from among the codes having the same content. Therefore, high-quality communication can be performed.

(5) In addition, the oscillation frequency control circuit linearly changes the frequency within the repetition period of the sweep. Thus, the waveform of a frequency change caused by sweep is a triangular shape.

Advantages

According to the present invention, establishment of communication between a radio transmitter and a radio receiver can be ensured with a simple circuit by compensating for the influence of a frequency drift in a low-accuracy oscillator.

Brief Description of the Drawings

[Fig. 1] Fig. 1 is a block diagram showing the configuration of a radio receiver according to a first embodiment.

[Fig. 2] Fig. 2 is a block diagram showing the configuration of a radio receiver according to a second embodiment.

[Fig. 3] Fig. 3 includes schematic diagrams of a sweep waveform and a radio signal according to a third embodiment.

[Fig. 4] Fig. 4 is a block diagram showing the configuration of a

radio receiver according to a fourth embodiment.

[Fig. 5] Fig. 5 is a block diagram showing the configuration of a radio transmitter according to a fifth embodiment.

Reference Numerals

1 - aerial wire

2 - VCXO

3 - frequency multiplier

4 - mixer circuit

5 - sweep generator circuit

6 - BPF

7 - frequency discriminator

8 - comparator

9 - phase comparator

10 - adding circuit

11 - LPF

12 - VCO

13, 14 - frequency divider circuit

15 - voltage-controlled resonant circuit

16 - code generator

20 - amplifier circuit

21 - surface acoustic wave resonator

22 - variable capacitance diode

23, 24 - frequency control terminal

25 - switch circuit

26 - phase device

27 - quadrature detector circuit

50 - PLL synthesizer

51 - high-frequency amplifier

52 - intermediate-frequency amplifier

53 - DC amplifier

54 - amplifier

56 - quartz oscillator

57 - inverting amplifier

100 - radio receiver

Best Mode for Carrying Out the Invention

As a preferred embodiment of the present invention, a first embodiment in which an oscillation frequency of a superheterodyne radio receiver that receives an FSK radio signal is swept will be described.

Fig. 1 is a block diagram showing the configuration of the first embodiment.

In this embodiment, a radio receiver 100 receives from an aerial wire 1 a radio signal having a carrier in 315 MHz frequency band, and outputs the radio signal to a high-frequency amplifier 51. A frequency multiplier 3 multiplies an oscillation signal of a voltage-controlled 38 MHz oscillator VCXO 2 by eight. The VCXO 2 and the frequency multiplier 3 constitute a local oscillation circuit. In an ideal state in which no frequency drift occurs and sweep is not performed, when the frequency multiplier 3 multiplies the frequency of the VCXO 2, which is 38.0375 MHz, by eight, a local oscillation signal of 304.3 MHz is acquired. In addition, a mixer circuit 4 mixes this local oscillation signal with the carrier of 315 MHz, and an intermediate-frequency signal (hereinafter, referred to as an IF signal) of 10.7 MHz is acquired.

In practice, since a frequency drift occurs in each of the carrier frequency of the radio signal from a radio transmitter and the local oscillation signal of the local oscillation circuit of the radio receiver 100, these frequencies deviate to some extent. Thus, a sweep signal from a sweep generator circuit 5 is applied to a control terminal of the VCXO 2, and the oscillation frequency is swept. In the sweep generator circuit 5, sweep is not stopped at any frequency in the middle of a sweep operation.

The mixer circuit 4 mixes the swept local oscillation signal with the radio signal received by the aerial wire 1 to produce an IF signal. A band pass filter 6 in the subsequent stage filters the IF signal, and outputs the filtered IF signal to a frequency discriminator 7 via two intermediate-frequency amplifiers 52A and 52B. The frequency discriminator 7 performs FM detection on the IF signal, and outputs the IF signal to a comparator 8 via a DC amplifier 53. The comparator 8 performs digital signal demodulation on the IF signal.

For example, when the carrier frequency of the radio signal is 313.5 MHz by 1.5 MHz deviation due to a frequency drift, if the sweep generator circuit 5 is not used, the frequency of the local oscillation signal is maintained at 304.3 MHz, which is a predetermined value. Thus, the frequency of the IF signal is 9.2 MHz, which deviates from the above-described specified frequency of the IF signal, 10.7 MHz. Thus, the radio signal cannot be received, and demodulation of a transmission signal cannot be performed.

In contrast, as in the present invention, in a case where sweep is repeatedly performed over a frequency bandwidth of, for example, 5 MHz using the sweep generator circuit 5, the local oscillation frequency is swept over a width of 2.5 MHz in each of the upward and downward directions centered on 304.3 MHz. When the local oscillation frequency reaches 302.8 MHz, the frequency of the IF signal reaches 10.7 MHz, which is the specified value. Thus, the transmission signal can be demodulated. Since the sweep width of the local oscillation frequency is 5 MHz, if the carrier frequency is within a range between 312.5 MHz and 317.5 MHz, that is, if the deviation of the frequency is ±2.5 MHz or less, transmission and reception can also be performed. Since sweep is not stopped in the middle of a sweep operation, a period during which the frequency of the IF signal is within a range in which transmission and reception can be performed is short.

In addition, if the carrier frequency is 315.0 MHz, which is the

predetermined value, and the frequency of the local oscillation signal is 302.8 MHz by 1.5 MHz deviation from 304.3 MHz, which is the predetermined value, normally, the frequency of the IF signal is 9.2 MHz, which deviates from the specified value, 10.7 MHz. Thus, the transmission signal cannot be demodulated. However, in this embodiment, the frequency of the local oscillation circuit is swept over a frequency bandwidth of, for example, 5 MHz, which is 2.5 MHz in each of the upward and downward directions. Thus, even if the local oscillation signal deviates by 1.5 MHz due to a frequency drift, the deviated frequency of the local oscillation signal is swept, and a period during which the local oscillation frequency is the predetermined value, 304.3 MHz, is generated. Thus, the IF signal reaches the specified value, 10.7 MHz, and the transmission signal can be demodulated within the period. Accordingly, if the oscillation frequency of the local oscillation circuit is within the range between 301.8 MHz and 306.8 MHz, that is, if the deviation of the frequency of the local oscillation circuit due to the frequency drift is ±2.5 MHz or less, the radio signal can also be received. Since sweep is not stopped in the middle of a sweep operation, a period during which the frequency of the IF signal is within a range in which transmission and reception can be performed is short.

In addition, even in a case where both the carrier frequency and the center frequency of the sweep range of the local oscillation circuit deviate, if only a period during which the frequency of the IF signal is within a specified range is generated anywhere in the sweep range, reception can be performed. Thus, the sweep range of the local oscillation circuit can be determined in accordance with assumed or permitted maximum values of deviations in the transmitter and the receiver.

The present invention is not limited to this embodiment. The present invention can also be applied to an ASK digital data

modulation method and analog data modulation method, as well as the FSK digital data modulation method and analog data modulation method. In addition, the present invention is also applicable to a double-superheterodyne radio receiver or the like.

In addition, as a circuit for performing FSK demodulation, a detector circuit, such as a ratio detector, a Foster detector, or a slope detector, may be used, as well as a frequency discriminator. In addition, a sweep waveform may be a triangular waveform, a staircase waveform, or the like. In order to generate a staircase waveform, a sweep generator circuit including a counter circuit for generating a digital value and an analog/digital converter circuit that are connected to each other can generate an analog-converted counter value as a sweep signal.

As a preferred embodiment of the present invention, a second embodiment in which a local oscillation frequency of a direct-conversion radio receiver that receives a QPSK radio signal is swept is described next. Fig. 2 is a block diagram showing the configuration of this embodiment.

In the direct-conversion radio receiver, using a quadrature detector, a high-frequency signal from an antenna is directly multiplied by a local oscillation signal so as to be converted into a baseband quadrature signal, and demodulation is performed. Since a carrier frequency is selected based on the frequency of the local oscillation signal, if the oscillation frequency of the local oscillation signal is swept, the received carrier frequency is equivalently swept.

In this embodiment, the radio receiver 100 receives a radio signal from the aerial wire 1, and outputs to each of two quadrature detector circuits 27A and 27B a signal amplified by two high-frequency amplifiers 51A and 51B. The frequency multiplier 3 performs multiplication on an oscillation signal of the voltage-controlled

oscillator VCXO 2. The VCXO 2 and the frequency multiplier 3 constitute a local oscillation circuit. In addition, a local oscillation signal from the local oscillator circuit is output to the quadrature detector circuits 27A and 27B via a phase device 26 as two signals having a phase difference of 90 degrees. Here, the local oscillation frequency is swept by applying a sweep waveform from the sweep generator circuit 5 to a frequency control terminal of the VCXO 2. In the sweep generator circuit 5, sweep is not stopped at any frequency in the middle of a sweep operation. The quadrature detector circuit 27A directly multiplies the radio signal by the local oscillation signal to convert the radio signal into a baseband quadrature signal, and outputs the baseband quadrature signal via an LPF 11A and an amplifier 54A. In addition, the quadrature detector circuit 27B directly multiplies the radio signal by the local oscillation signal to convert the radio signal into a baseband quadrature signal, and outputs the baseband quadrature signal via an LPF 11B and an amplifier 54B.

In a case where a frequency drift occurs in a carrier from a radio transmitter, if the frequency of the local oscillation circuit of the radio receiver is swept over a frequency bandwidth that is equal to or more than the width of the frequency drift, the received carrier frequency varies over a frequency band including a design value. Thus, in the process of the sweep operation, the actual carrier frequency can be temporarily selected based on the frequency of the local oscillation signal. Thus, the radio signal can be received, and a transmission signal can be demodulated. Accordingly, as a result, the drift in the carrier frequency is compensated for.

In addition, in a case where a frequency drift occurs in the local oscillation signal of the radio receiver, if the frequency of the local oscillation signal is swept over a frequency bandwidth that is equal to or more than the width of the frequency drift in the local

oscillation signal, the received carrier frequency varies over a frequency band including a design value. Thus, in the process of the sweep operation, the radio signal at the specified carrier frequency is temporarily received, and demodulation is performed. Accordingly, as a result, the frequency drift in the local oscillation signal is compensated for.

As a third preferred embodiment of the present invention, a keyless entry system adopted in a superheterodyne radio receiver that performs sweep with a sweep signal having a sawtooth waveform is described next. The present invention can also be applied to a radio communication system that transmits and receives a control code having a short length as well as the keyless entry system.

Fig. 3(A) shows the frequency sweep waveform of the receiver, and Fig. 3(B) is a schematic diagram showing a data signal of a transmitted radio signal.

In this example, a radio transmitter that transmits the radio signal is a so-called key used in the keyless entry system, the key being integrated with a car key, and transmits the radio signal in 315 MHz frequency band as a pulse-burst signal. In addition, a control signal, an identification code, an FEC error correction code, and the like are superimposed together on one burst in a bit/byte interleave method. Thus, the radio receiver is capable of demodulating data even with a certain degree of BER, and since the bit/byte interleave method is used, a multipath environment or the like can be supported. In addition, burst portions (bit sequences) on which the same content is superimposed are repeatedly transmitted a plurality of times during a user key operation.

When the data communication speed is 2400 bps and the amount of information superimposed on a burst is 25 bits, it takes about 10.4 milliseconds (period T3) to transmit one burst, as shown in Fig. 3(B). In addition, if it takes about 1 second (period T1) for a user of the

keyless entry system to perform an operation for the key, which is the radio transmitter, about 96 bursts having the same content are repeatedly transmitted during period T1 in accordance with the user operation.

In the radio receiver, when a sweep generator circuit applies to a control terminal of a local oscillation circuit a sweep signal having a sawtooth waveform in a period of 200 milliseconds (period T2), as shown in Fig. 3(A), the radio transmitter transmits about 18 bursts during the sweep period (T2).

In addition, in a case where frequencies at which a transmission signal can be demodulated from an IF signal are a frequency bandwidth of ±25 kHz centered on 400 kHz and sweep is performed over a frequency bandwidth of ±150 kHz centered on 400 kHz, a period during which the frequency of the IF signal is within the frequency bandwidth of ±25 kHz centered on 400 kHz is about 33 milliseconds (period T4), as shown in Fig. 3(C). About 3.2 bursts can be transmitted and received during the period T4.

Thus, the radio signal of the keyless entry system is demodulated, and authentication of the radio transmitter is performed in accordance with an identification code for each car superimposed on the radio signal. When authentication of the identification code is achieved, an operation designated by a control code, such as opening of a door, can be controlled.

As in the above-described example of the keyless entry system, if the amount of information is small, a burst signal can be transmitted by short-time radio communication. Thus, even if the period during which the IF signal has a predetermined frequency at which demodulation can be performed is short, most of information included in one burst signal can be transmitted. In addition, since the radio transmitter repeatedly transmits radio signals of the same content, the radio receiver is capable of receiving bursts of the same content

a plurality of times. Thus, since information received in a burst with the best BER from among a plurality of bursts is demodulated, transmission and reception of a radio signal with a high quality and a reduced BER compared with a case where sweep is not performed can be realized.

Here, a case where the carrier frequency of the radio receiver deviates due to the influence of a frequency drift is described. In Fig. 3(C), a deviated signal is represented by a solid line A, a signal of a design value before the deviation is represented by a broken line B.

If a frequency drift occurs in the carrier frequency from the key of the keyless entry system, the frequency of the IF signal deviates from the broken line B to the solid line A. Thus, a burst signal within a section B1, which is an IF signal originally having a frequency at which demodulation can be performed, which is about 10.7 MHz, becomes an IF signal having a frequency at which demodulation cannot be performed. However, since, due to mixture with a local oscillation signal, a burst signal within a section A1 becomes an IF signal having a frequency of 10.7 MHz at which demodulation can be performed, even if the frequency drift occurs, the IF signal has a predetermined frequency at which demodulation can be performed.

In addition, if a plurality of bursts can be received, since a burst having a relatively excellent BER is included in the plurality of bursts, transmission and reception of a radio signal with a high quality and a reduced BER compared with a case where sweep is not performed can be realized.

As a fourth embodiment, an example in which a local oscillation circuit of a radio receiver is structured using a PLL synthesizer is described next. The use of the PLL synthesizer increases a selectable range of a local oscillation frequency. Fig. 4 is a block diagram of the radio receiver in this embodiment.

The radio receiver 100 receives from the aerial wire 1 a radio signal having a carrier in 315 MHz frequency band, and outputs the radio signal to the high-frequency amplifier 51.

In a PLL synthesizer 50, a frequency divider circuit 13 divides the frequency of an oscillation signal of a VCO 12, and supplies the frequency-divided signal to one input of a phase comparator 9. A frequency divider circuit 14 divides the frequency of an oscillation signal of a resonant circuit constituted by a quartz oscillator 56 functioning as a reference signal source and an inverting amplifier 57, and supplies the frequency-divided signal to the other input of the phase comparator 9. The phase comparator 9 compares the phases of the two signals from the frequency divider circuit 13 and the frequency divider circuit 14, and an adding circuit 10 provided in the subsequent stage of the phase comparator 9 adds a sweep signal from the sweep generator circuit 5 and an output of the phase comparator 9. An LPF 11 filters the added signal and determines a loop characteristic. An output of the LPF 11 is supplied to a frequency control terminal of the VCO 12. Accordingly, the VCO 12 outputs the swept local oscillation signal to the mixer circuit 4 via an amplifier 54.

In addition, by mixing the local oscillation signal with the carrier of 315 MHz in the mixer circuit 4, an intermediate-frequency signal of 10.7MHz (hereinafter, referred to as an IF signal) is acquired.

The mixer circuit 4 mixes the swept local oscillation signal with the radio signal received by the aerial wire 1 to produce an IF signal. The band pass filter 6 in the subsequent stage filters the IF signal, and outputs the filtered IF signal to the frequency discriminator 7 via the two intermediate-frequency amplifiers 52A and 52B. The frequency discriminator 7 performs FM detection on the IF signal, and outputs the IF signal to the comparator 8 via the DC amplifier 53.

The comparator 8 performs digital signal demodulation on the IF signal.

Normally, the PLL circuit intends to always output a signal at a predetermined frequency. However, if the oscillation frequency of the VCO 12 deviates from a predetermined value, the supply voltage of the VCO 12 is controlled such that the oscillation frequency of the VCO 12 is stabilized at the predetermined value. Thus, the oscillation frequency of the VCO 12 is moderately tuned to the predetermined frequency in accordance with a time constant of the PLL loop of the PLL synthesizer 50.

Here, the sweep generator circuit 5 generates a sweep signal having a triangular waveform or the like, and the adding circuit 10 adds the sweep signal to an output of the phase comparator 9. In a normal PLL circuit, the output of the phase comparator 9 is directly input to the LPF 11 and proper feedback is performed. However, with the provision of the sweep generator circuit 5, a transmission signal is superimposed as a disturbance on the amount of feedback. As a result, the frequency of the local oscillation signal, which is an output of the PLL synthesizer 50, is swept with the lapse of time. However, since an operation for sweeping the oscillation frequency of the VCO 12 in accordance with a sweep signal is antagonistic to a tuning operation of the PLL circuit, although the waveform of a frequency change of the local oscillation signal, which is an output of the PLL synthesizer 50, and the waveform of the sweep signal have the same cycle, the phase and waveform of the local oscillation signal are different from the phase and waveform of the sweep signal.

As described above, even if a PLL synthesizer and a sweep generator circuit are used, an IF signal can be swept. Sweep is not stopped in the middle of a sweep operation.

If a carrier frequency deviates from a predetermined value due to the influence of a frequency drift, normally, the frequency of an IF signal deviates from a specified frequency at which demodulation can

be performed. Thus, a transmission signal cannot be demodulated. However, in this embodiment, the sweep generator circuit 5 sweeps the local oscillation frequency from the PLL synthesizer 50. Thus, the frequency of an IF signal acquired by mixing the local oscillation signal and a radio signal by the mixer circuit 4 is swept. Due to the deviation of a carrier frequency caused by a frequency drift and sweep of the frequency of the local oscillation signal, a period during which the frequency of the IF signal is within a predetermined range is generated. Thus, a transmission signal can be demodulated in the period during which the frequency of the IF signal is within the predetermined frequency range, and a radio signal can be received. Since sweep is not stopped in the middle of a sweep operation, a period during which the frequency of the IF signal is within a range in which transmission and reception can be performed is short.

In addition, even when a carrier frequency is a predetermined value, if a local oscillation frequency from the PLL synthesizer 50 deviates from a predetermined value, normally, the frequency of an IF signal also deviates from a specified value. Thus, a transmission signal cannot be demodulated. However, in this embodiment, the local oscillation frequency deviated due to a frequency drift is swept. Thus, a period during which the local oscillation frequency is within a predetermined range is generated. Even if the center of a sweep range of the local oscillation frequency from the PLL synthesizer 50 deviates from a proper value of the local oscillation frequency, a radio signal can be received as long as the predetermined value is included in the sweep range. Since sweep is not stopped in the middle of a sweep operation, a period during which the frequency of the IF signal is within a range in which transmission and reception can be performed is short.

As described above, even in a case where the sweep generator circuit 5 is added within the PLL synthesizer 50, the influence of a

frequency drift can be avoided by sweeping an IF signal. In addition, with the use of the PLL synthesizer 50, an inexpensive quartz oscillator XO of a general-purpose frequency can be used as a reference signal source. Thus, the total cost can be reduced.

A local oscillation signal can be swept by using an enormously large time constant of the PLL circuit and using a sweep signal of a rectangular waveshape having a cycle longer than a time required for the PLL synthesizer to perform tuning. In this case, the frequency of the local oscillation signal changes from a predetermined value in accordance with rising of the sweep signal of the rectangular waveshape. Then, the local oscillation frequency is moderately converged into the predetermined value in accordance with a tuning operation performed by the PLL synthesizer. Then, the local oscillation signal starts to change again in accordance with falling of the sweep signal, and the local oscillation frequency is converged into the predetermined value in accordance with a tuning operation. With the repetition of such frequency modulation, the local oscillation frequency can be periodically swept.

As a fifth embodiment, an example in which a carrier frequency of a radio transmitter is swept is shown in Fig. 5.

In the fifth embodiment, a radio transmitter that transmits an FSK-modulated carrier in 325 MHz frequency band is described. In this radio transmitter, a variable capacitance diode 22 is connected to a surface acoustic wave resonator 21, a frequency control terminal 23 connected to the sweep generator circuit 5 is connected to the cathode of the variable capacitance diode 22, and a frequency control terminal 24 connected to a code generator 16 is connected to the anode of the variable capacitance diode 22. The code generator 16 includes a switch circuit 25 for performing predetermined control for keyless entry. A sweep signal from the sweep generator circuit 5 is applied to the frequency control terminal 23 of a voltage-controlled resonant

circuit 15, and a control code signal from the code generator 16 is applied to the frequency control terminal 24 in accordance with an operation using the switch circuit 25. The voltage-controlled resonant circuit 15 and an amplifier circuit 20 constitute an oscillation circuit.

Applying the sweep signal to the frequency control terminal 23 of the voltage-controlled resonant circuit 15 sweeps the oscillation frequency, and applying voltage to the frequency control terminal 24 of the voltage-controlled resonant circuit 15 performs FSK modulation. Accordingly, the frequency of the surface acoustic wave resonator 21 is modulated using the sweep signal and the code signal, the modulated signal is amplified by the amplifier circuit 20, and the amplified signal is transmitted as a radio signal.

If the frequency of the surface acoustic wave resonator 21 of the radio transmitter deviates from a predetermined value due to the influence of a frequency drift, normally, the frequency of an IF signal in a radio receiver deviates from a predetermined frequency at which demodulation can be performed. Thus, a transmission signal cannot be demodulated. However, in this embodiment, the frequency of the surface acoustic wave resonator 21 deviated due to a frequency drift is swept by the sweep generator circuit 5. Thus, the deviated frequency is modulated by sweep, and a period during which the frequency of the surface acoustic wave resonator 21 is a predetermined value is generated. Even if the center of a sweep range of the frequency of the surface acoustic wave resonator 21 deviates from a proper value for the surface acoustic wave resonator 21, the radio receiver is capable of receiving a radio signal as long as the predetermined value is included in the sweep range. Sweep is not stopped in the middle of a sweep operation. As a result, the FSK-modulated codes are demodulated from the received radio signal, a control code and an identification code are read, and a predetermined

operation for keyless entry can be performed.

In addition, even when the frequency of the surface acoustic wave resonator 21 of the radio transmitter is a predetermined value, if the frequency of a local oscillation circuit of a radio receiver deviates from a predetermined value, normally, the frequency of an IF signal in the radio receiver also deviates from a predetermined value. Thus, a transmission signal cannot be demodulated. However, in this embodiment, the frequency of the surface acoustic wave resonator 21 of the radio transmitter is swept. Thus, due to sweep of the frequency of the surface acoustic wave resonator 21 and the deviation of the local oscillation frequency of the receiver caused by a frequency drift, a period during which the frequency of an IF signal in the receiver is a predetermined value is generated. As a result, a transmission signal can be demodulated in the period during which the frequency of the IF signal is the predetermined value. Thus, the FSK-modulated codes are demodulated, the control code and the identification code are read, and a predetermined operation keyless entry can be performed.